Secretary's PTC Progress Report to the Congress—
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Outline for Discussion by the Implementation Task Force

NOTE: The immediate task before the Working Group is preparation of its own report to the Administrator. Preparation of the report in a format suitable for use as a progress report to the Congress will assist FRA in meeting its statutory responsibilities. The Administrator will review the report to ensure that it represents Administration policy. The Office of the Secretary of Transportation, with review by the Office of Management and Budget, will have final approval of this report. FRA seeks assistance from the PTC Working Group in developing this report *and will clearly distinguish in the final Report to Congress any material approved by the RSAC from any material not approved by the RSAC*.

Executive Summary in Front *(FRA will do**, Grady Cothen** - point of contact)*, then:

Introduction

This is a report of the Railroad Safety Advisory Committee (RSAC) to the Federal Railroad Administrator on the status and future of Positive Train Control (PTC) systems. The report was prepared by the RSAC PTC Working Group, which worked for over a year to gather facts, review options and deliberate on the best approach to encouraging rapid and successful deployment of PTC technology. The working group was comprised of representatives of freight and passenger railroads, labor organizations, industry equipment suppliers and State departments of transportation, assisted by Federal Railroad Administration (FRA) counsel and staff. ~~Although~~ The implementation of PTC systems is a broad and complex subject. As such the working group members ~~could~~ were not able to agree on all issues related to deployment of PTC, although the group was able to advance ~~our~~ FRA's understanding of the issues. In addition, the working group identified important actions that should be taken to create a favorable climate for introduction of PTC systems. The RSAC requests that the full text of this report be included in the Secretary of Transportation's forthcoming progress report to the Congress on PTC systems.

Since the early 1980's, the railroad industry has recognized the possibility of using data radio communications, emerging microprocessor-based ~~control~~ systems, and other contemporary technologies to perform enhanced train control functions. In concept, this approach should make it possible to end most train-to-train collisions, enforce restrictions on train speed, and enhance protection~~s~~ for roadway workers–~~all~~ at a cost lower than would be expected using traditional approaches. ~~Many~~ Some in the industry have identified business benefits that might accrue from institution of such systems. All parties involved in the RSAC PTC process seek to define systems that are safety-effective, cost-effective, and interoperable as a railroad industry standard. These are the key elements in ensuring that promised benefits of the technology may soon be achieved in actual deployments. ~~, and FRA has identified other societal purposes that such systems could help achieve.~~

Industry standards efforts and test programs have developed several variations of this concept, but railroads have not yet judged it technically and financially prudent to make large scale capital~~-scale~~ investments required to complete systems development and to deploy the technology on a broad scale.

Meanwhile, the National Transportation Safety Board (NTSB) and the Federal Railroad Administration (FRA) have continued to urge that the potential safety benefits of PTC be realized at the earliest possible date.

One of the difficulties in realizing ~~of~~ the benefits of PTC systems is the number of entities that need to cooperate to make it happen. With the goal of encouraging collaboration between the public and private sectors and gathering information to enlighten public policy, Administrator Molitoris requested the RSAC to investigate this issue and recommend appropriate action. On September 30, 1997 the RSAC accepted three PTC-related tasks. In summary, the tasks were to:~~=~~

- Prepare a descriptive report to facilitate understanding of current PTC technologies, definitions, and capabilities (Task 97-4)

- Complete analysis and prepare recommendations to address any remaining issues regarding the feasibility of implementing fully integrated PTC systems, evaluate factors that may guide decisions on how PTC could yield optimum benefits in relation to costs, and determine the timetable over which such systems could be deployed–taking into account the need to first complete testing and revenue demonstration of any new system (Task 97-5); and

- Facilitate implementation of software-based signal and operating systems by discussing potential revisions to the Rules, Standards and Instructions (49 CFR Part 236) to address processor-based technology and communication-based operating architectures, including consideration of disarrangement of micro-processor-based interlockings, performance standards for PTC systems at various levels of functionality (safety-related capabilities), and procedures for introduction and validation of new systems (Task 97-6).

The results of the first two tasks are reflected in the body of this report. The third task—preparation of performance standards for processor-based signal and train control technology—is well underway. The report also describes the PTC Working Group's efforts to draft proposed regulations that will be technologicall~~y~~y neutral and will facilitate the onset of PTC deployment by creating a higher degree of predictability regarding the manner in which regulatory approval will be achieved.

This ~~This~~ report ~~does not~~ was not answer one of the most urgent questions regarding PTC–i.e., whether the FRA should mandate the institution of PTC functions on any significant portion of the Nation's rail lines. In January of 1998, the Board of Directors of the Association of American Railroads (AAR) accepted a challenge from Secretary of Transportation Rodney Slater and Administrator Molitoris to enter into a partnership for PTC systems development. The venue for this effort is a project initially funded by FRA under section 1010 of the Intermodal Transportation Efficiency Act of 1991 (now section 1103(3)(2) of the Transportation Equity Act for the 21st Century) on the designated high-speed passenger rail line between Chicago, Illinois, and St. Louis, Missouri. The project unites the State of Illinois, FRA, and the Class I railroads through the AAR (including the Union Pacific Railroad as owner of the line and Amtrak as the passenger train operator) in seeking development of a PTC system that can support high-speed passenger operations as well as conventional freight service with a high degree of safety and efficiency. The standards developed as a part of this project will be available for use with PTC developments on other rail lines.

The first product of the Illinois Project, expected to be completed within this calendar year, will be industry standards for interoperability of PTC systems. Interoperability (which is more precisely described

~~below~~herein) refers to the ability of lead locomotives from one railroad to respond to the control of another railroad's PTC system while traversing that railroad's lines. Since shared power arrangements and various types of joint operations are becoming ~~the rule~~more widespread, rather than the exception in contemporary railroading, interoperability ~~will be critical~~is important to realizing the safety and other benefits of PTC.

In addition to writing rules for the performance of PTC systems, the PTC Working Group will remain active over the next year (and perhaps beyond) to track the progress of the Illinois Project and other PTC efforts and to act as a broad-based advisory panel in support of these activities~~. Should progress be arrested or delayed inappropriately, the working group will report to the RSAC and the RSAC will express its concerns to the Administrator for further dissemination, as appropriate~~. The working group will report to the FRA Administrator regarding the progress toward PTC implementation and any actions needed to facilitate system deployment.

~~The record assembled by the working group generally supports conclusions regarding costs and benefits of PTC systems that were expressed in FRA's 1994 Report to Congress entitled ***Railroad Communications and Train Control***. Although the working group was able to define certain elements of benefits and costs with greater precision, the fact remains that–using cost/benefit techniques required for regulatory analysis—safety benefits alone do not appear to support the required investments except where high-speed passenger operations are conducted~~Making these investments attractive to freight and passenger railroads requires that PTC technology be shown to be reliable and capable of addressing customer needs in a more efficient manner than would be the case using alternative technology. The working group is hopeful that the Illinois Project and other technology development efforts underway on major railroads will provide the confidence needed to support, first, large-scale revenue demonstration of the technology and, second, broad deployment on the core of the national rail system.

Over the past year of deliberations, the PTC Working Group has come to appreciate that deployment of PTC involves significant technical challenges and will require a predictable and progressive public policy environment. PTC systems will not be deployed at an early date unless all responsible parties play a constructive role in advancing the technology and removing technical, economic and institutional barriers. The final section of the report addresses conclusions and recommendations that can provide the most favorable climate for development and deployment of PTC systems. Since development of policy within the Executive Branch of the United States Government requires coordination and clearance not feasible within the time available for preparation of this report, conclusions and recommendations related to Federal action should be viewed as the opinions of the non-Federal members of the RSAC. There will be materials published ~~absent adoption in materials~~ subsequently ~~published~~ by the Department of Transportation, specifically identifying recommended Federal actions.~~.~~

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Safety is the primary focus of this effort. The National Transportation Safety Board (NTSB) has long advocated the implementation of systems that can provide positive train separation. The *"NTSB Most Wanted List of Transportation Safety Improvements"* includes the following recommendation: "Require a railroad collision avoidance system."

The 1994 Report to Congress concluded that the various attributes of PTC would improve railroad safety and enable improved management of train operations in a variety of ways and at lower cost than conventional train control systems. Subsequently, the FRA created a Positive Train Control (PTC) Railway Safety Advisory Committee (RSAC) that defined three core functions of PTC. These core functions would:

- Prevent train to train collisions (positive train separation).
- Enforce speed restrictions, including civil engineering restrictions and temporary slow orders.
- Provide protection for roadway workers and their equipment operating under specific authorities

Recap: 1994 Report and Action Plan (FRA will do, Grady Cothen **- point of contact)**

III. Train Control Systems and PTC architectures *(RSAC Progress Report Group, [points of contact are Chuck Dettmann, Grady Cothen, and James Stem until team make-up has been determined])*

A. Train control systems and allied technologies [explain similarities and differences between train control systems and other technologies than address one or more PTC functions]

Commentary: Add introduction of how technology has enabled advancements in safety and efficiency of operations. Add some history; e.g., describe traditional signaling technology (Possibly extract portions of Bob Gallamore's article in Railway Age). Discuss proven safety record, fail safe concepts, closed loop, cab signals, and PTC concepts. – Need to be sure it doesn't duplicate information presented in Section I. Some of this material is in the 1994 report.

Should compare different systems based the system functional elements (location system, communications, operator display, how/where safety problem is identified, how system reacts to detected problem). Should discuss how different systems address different risk areas and achieve different levels of risk reduction.

Possible areas in which systems may differ: approach to monitoring and detection, processing, prevention, actions taken.

As with all transportation systems, railroad operation requires the management of time and space. By controlling time, space can be allocated for operations. With low density operations time is less critical, but with high speed, dense operations time becomes more critical. The evolution of railroad control systems followed this principle. In other words, greater knowledge of location and faster communication of that knowledge is key to improving railroad capacity, efficiency and safety. The railroad is a single degree of freedom system. The train can go either forward or in reverse, but **on single track** cannot pass~~;~~ except where there are sidings. Trains travelling at greater than restricted speed (15-20 mph or so) cannot stop within sight distance, and systems that provided for safe operation that did not rely on the operator seeing an opposing train were developed. The railroads developed rule based systems to allow for greater speeds and to manage the allocation of space.

There are three major methods of train operations on main tracks in the U.S; signal indications; ~~**voice train movement authorities**~~ **mandatory directives**; and manual block rules. PTC systems under development are centered on one or more of these methods of operation.

Operations by Signal Indications

Operations by signal indications occur at interlockings, in traffic control systems or automatic block signal systems on two main tracks arranged for movement with the current of traffic. Trains having authority to enter these systems are governed by the indications of signal aspects that are arranged to provide for movement at maximum authorized speeds; provide sufficient distance to slow a movement in approach to the point where speed is to be reduced; and provide sufficient distance to stop a movement at the point where a stop is required. Absent control devices that supplement the signal systems to enforce maximum authorized speed and speed reductions (e.g., automatic train control or automatic trainstop), compliance is dependent upon the locomotive engineer to properly control the speed of a train. With or without supplementary control devices, it is dependent upon the locomotive engineer to stop a train at a point where a stop is required.

Operations by ~~Voice Train Movement Authorities~~ ***Mandatory Directives***

Operations by ~~train orders~~ **mandatory directives** may occur in either automatic block signal territory or non signaled territory. ~~Train orders are m~~**M**andatory directives **are orders** that affect the movement of trains and are identified on various railroads as **train orders,**track warrants, track permits, track bulletins, block authorities and Form D. ~~Train orders~~ **Mandatory directives** provide the authority for the movement of a train and may be used for the protection of roadway workers and on track equipment.

~~Train orders~~ **Mandatory directives** are orally issued by the dispatcher to a train crew member who must repeat the ~~orders~~ **directives** back to the dispatcher for verification of correctness. ~~Train orders~~ **Mandatory directives** authorize the movement of a train between specific points and provide instructions for meeting or passing other trains, speed restrictions and other special conditions. Where automatic block signals supplement operations by ~~train orders~~ **mandatory directives**, indications of signal aspects furnish train crew members information about block conditions in advance and provide sufficient spacing to slow or stop a train as may be required. The dispatcher is relied upon to issue ~~train orders~~ **mandatory directives** that provide for the safe movement of trains. It is dependent upon train crew members to comply with both the instructions contained in ~~train orders~~ **mandatory directives** and the indications of a block signal system **control the speed of a train and stop where a stop is required**.

Operations by Manual Block Rules

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Manual block rules are used for the movement of trains on designated portions of several railroads. In a manual block system the railroad is segmented into blocks of designated lengths. ~~Train orders~~ **Mandatory directives** are issued by a block operator or dispatcher and provide authority for a train to enter a block or blocks. No train may be permitted to enter a block occupied by a passenger train or an opposing train; a passenger train may not enter a block occupied by another train; but a freight train may follow a freight train into a block provided the following train proceeds prepared to stop in one-half the range of vision but not exceeding 20 mph. Block operators are relied upon to assure each block is unoccupied before permitting a train to enter the block. It is dependent upon train crew members not to enter a block without authority, to properly control the speed of the train and stop where a stop is required.

Other Methods of Operation

For branch lines, industry tracks, other auxiliary tracks and yards, various methods of operations are employed for the movement of trains. Voice rules and yard rules are used in yard operations and switching services on industry tracks. Yard limit rules are used on main tracks extending through yards and stations and on branch lines. Timetable special instructions are utilized on branch lines, industry tracks and in conjunction with train orders on main tracks. All of these methods of operations rely upon dispatchers, operators, yardmasters and train crew members to be learned in the rules governing the methods of operations, issue succinct orders orally, and comply with all the requirements. Certain PTC projects have addressed train operations on auxiliary tracks, branch lines and yards in order to restrict unauthorized entry onto the main track.

Requirements for Signal and Train Control Systems

Federal ~~statutes and~~ regulations exist that prohibit the operation of a freight train at a speed of 50 or more miles per hour or a passenger train at a speed of 60 or more miles per hour unless a manual block system or a block signal system is installed**;** and prohibits the operation of any train at 80 or more miles per hour unless an automatic cab signal, trainstop or train control system is installed.

An automatic block signal system or a traffic control system is required to support the installation of automatic cab signal, trainstop or train control systems. Cab signal, trainstop and train control devices are installed on board locomotives and, accordingly, supplement the block signal or traffic control system. Track circuits or devices along the wayside are used to communicate signal system status to the on board equipment.

Automatic cab signals are inductively connected to track circuits and convey aspects on board that indicate the condition of the block being traversed and the blocks in advance. No enforcement is provided by automatic cab signals and train crew members are relied upon to comply with the indications displayed, properly control~~ling~~ the speed of ~~the~~ **a** train and **to** stop~~ping~~ where a stop is required.

Automatic train control devices augment automatic cabs signals and provide enforcement of speeds associated with signal indications. When a **more** restrictive cab signal indication is obtained, the locomotive engineer must immediately take action to reduce the train speed to that prescribed by the signal indication or the train control device will initiate a brake application to stop the train. The most restrictive cab signal indication permits a speed not exceeding 20 mph. It is dependent upon the locomotive engineer, at speeds of 20 mph or less, to **properly control the speed of a train and to** stop ~~the train~~ w**h**ere a stop is required.

Automatic trainstop devices also augment automatic cab signals but do not provide enforcement of speeds. When a **more** restrictive cab signal is obtained, the locomotive engineer must acknowledge the restrictive cab signal within a prescribed period of time or the trainstop device will initiate a brake application to stop the train. The locomotive engineer is relied upon to properly control the speed of ~~the~~ **a** train after acknowledging a restrictive cab signal and to stop ~~the train~~ where a stop is required.

An automatic trainstop device may be utilized without cab signals by being intermittently inductively connected to the wayside signal system (i.e., at each signal location). When a train passes a wayside signal displaying a restricting aspect, the locomotive engineer must acknowledge the restrictive indication within a prescribed period of time or the trainstop device will initiate a brake application to stop the train. It is dependent upon the locomotive engineer to control the speed of a train after acknowledging a restricting wayside signal indication and to stop ~~the train~~ w**h**ere a stop is required.

B. Current PTC system concepts <u>(see Rich McCord comments)</u>

Although the safety record of the railroads is exemplary, train collisions, overspeed derailments and accidents with maintenance of way workers, have generated a demand from the regulators, labor and management to develop cost-effective systems that could significantly reduce the risk of these types of accidents. As a part of the RSAC process, an accident review team was established to analyze the accident record and determine which accidents might be preventable by PTC. In order to accomplish this task, the accident review team develop four design concepts to reflect the broad range of capability that can address the PTC safety objectives, depending on operating territory and amount of risk reduction justified. The design concepts include augmentation of conventional cab signal systems, as well as the newer systems that use digital RF communications links.

The design concepts were developed based loosely on the functionalities of four current PTC projects (i.e. the Union Pacific Railroad (UPRR)/Burlington Northern Santa Fe (BNSF) Positive Train Separation (PTS) Pilot Project, the Amtrak/Michigan DOT Michigan Line Incremental Train Control System (ITCS) Project, and the BNSF Train Guard™ System Project), and the design specifications originally proposed for the UPRR/Illinois Department of Transportation (IDOT) St. Louis Line Project that were based on the Advanced Train Control Systems (ATCS) Specifications.

The four design concepts are hierarchical, in that each superior design incorporates all of the functions of the previous concept(s), and may either add functionality or scope (coverage) or both. The design concepts, from the least functionality/scope, to the most, are as follows.

PTC Level 1

This is the first level PTC design concept to meet the "core functions" as identified by the PTC RSAC:

- Prevent train to train collisions (i.e. positive train separation)
- Enforce speed restrictions, including civil engineering and temporary restrictions imposed by slow orders.
- Protection from train movements for roadway workers and their equipment operating under specific authorities.

This level of PTC ~~can utilize either an open or closed loop communication system,~~ **is** based on providing specific location information on nearby trains and maintenance of way crews to the lead locomotive of a train. Onboard enforcement is based on either the failure of the engine crew to acknowledge a warning of a nearby train, or maintenance of way crew, ~~failure to enter a signal aspect and obeying that aspect,~~ or exceeding permanent or temporary speed restrictions.

Most of these systems will use a radio frequency (RF) link to provide information to the lead locomotive of a train.

PTC Level 2

The next level PTC design will rely on a ~~closed loop communication~~ system. This level will depend on the issuance of specific movement authorities and the reporting of train and maintenance of way crew locations to the authority issuer. In addition, to the functionalities of PTC level 1, level 2 will provide:

- A computer aided dispatch (CAD) system designed to prevent the issuance of overlapping authorities, and provide for the issuance and enforcement of speed limits and restrictions.

- A digital communications link between the CAD system and the locomotives.

PTC Level 3

This design concept will also use a closed loop communication system and in addition to providing the functionalities of PTC levels 1 and 2, provide:

- Devices (Wayside Interface Units (WIUs)) that monitor each mainline wayside switch, signal, and protective device currently installed in traffic controlled territory, to reduce risk of operating over unsafe track. If new switches are required during implementation of a level 3 system, these switches will be tied into the WIU.
- WIUs in non-signaled territory that monitor switch and protective devices.

PTC Level 4

This is the highest level PTC design concept, and is largely based on the level 40 Advanced Train Control Systems (ATCS) specifications. In addition to providing the functionalities of PTC levels 1, 2 and 3, level 4 will provide:

- WIUs that monitor each mainline signal, switch and protective device. This may require the installation of devices on currently installed switches and protective devices.
- Additional protective devices, e.g. slide fences, anemometers, high water, dragging equipment, hot box detectors, etc.
- Additional track circuits, track continuity circuits or other risk reduction approaches for broken rail detection.
- Track forces terminals (e.g. laptops or other technology with data link) for roadway machinery to reduce the risk of accidents involving track forces outside their authority limits.

Open-Loop vs. Closed-Loop Control

~~There are two general types of control systems: open-loop and closed-loop. An open-loop system is one in which there is no direct or automatic function to cause an action to occur as a result of the control process. In a closed-loop system, the control function does directly create an action or output. A PTC system is not simply open-loop or closed loop as one system. There are a number of control loops within a PTC system, and each of these may independently be open or closed. For example, a PTC system typically includes a dispatch subsystem, a data communications subsystem, a wayside system, and an on-board system. The onboard system includes the function of initiating a brake application.~~

~~In the case of PTC, the distinction between open and closed-loop is most important as it relates to brake enforcement. In a closed-loop system, the PTC system will initiate a brake application if the conditions occur that require the train to stop. In an open-loop system, the train operator will get an alarm that a brake enforcement is called for, but it is up to the operator to initiate the brake application. Most PTC system configurations being developed or tested are closed-loop in the initiation of a brake application. Most existing types of train control are open-loop relative to brake application; the signal system or a verbal or written instruction may indicate that the train should stop before a certain point, but the brakes are only~~

~~applied if the train operator takes the appropriate action.~~

~~The major safety benefits of PTC, particularly implementation of the core PTC functions, are related to the fact that the brake initiation function is closed-loop.~~

[Note: Gary Pruitt to rewrite the above open loop - closed loop part for clarity.]

C: Introduction that compares and contrasts PTC with other methods of operation.

The railroad industry, with advocacy from the Federal sector, has pursued the development and implementation of communications-based train control systems for more than 15 years. The initial objective was to develop a train control system at less cost than conventional train control systems that provided equivalent or greater safety of train operations and business benefits. At least 12 projects have been undertaken during this time to develop communications-based train control systems, now colloquially termed Positive Train Control (PTC) systems. Three projects were unsuccessful, ~~two~~ **three** of which were abandoned ~~and one currently in suspension,~~ because of prohibitive costs. Nine of the projects are presently in various stages of development.

The developing PTC systems **are works in progress undergoing evolving change as technology develops. They** appear to fall into three categories: those that will become stand alone systems; those that will be integrated systems; and those that will be overlay systems.

- A PTC system of the stand alone type will not ~~only~~ **merely** augment the existing ~~signal~~ ~~train control~~ **signal** system but will absorb its functionality to the extent wayside signals may safely be removed. Safety computers at a central office, on the wayside and on board each locomotive will enforce the proper spacing of trains, all speeds and stop where a stop is required. Stand alone PTC systems will become the method of train operations.

- PTC systems of the integrated type will be so interconnected with the existing ~~signal~~ ~~train control~~ **signal** system that its functionalities will be extended to equipment on board each locomotive that will enforce all speed and stop requirements prescribed by both the PTC and signal systems. ~~The existing method of train operations will not change.~~ **The existing method of operations may or may not change.**

- PTC systems of the overlay type will provide for among other things, enforcement of all speed and stop requirements while utilizing the existing ~~train control~~ system as the primary method of train operations.

[Note: Grady Cothen suggested the ITS group's definitions be used in lieu of those above. I don't find the ITS definitions unless they are the ones Rich McCord used and have been extracted fromVI D on page 66 of the unedited master draft and reads as follows:]

Pure Overlay system. A pure overlay independent system PTC is installed on top of an existing train control or signal system. In an overlay system the control of the train is still under the jurisdiction of the dispatcher, and can be apparent or transparent to the operator, then the current operating rules will continue to apply.

Overlay with Enhanced Capabilities. An integrated - PTC System that adds additional safety critical functions, but retains the existing train control or signal system. This will use the existing code of operating rules to make decisions on train movements, but will require additions to those rules.

Stand Alone system. PTC is the only method of operation, such system will likely be used by the Alaska Railroad. With a stand alone system new operating rules would have to be drafted

Benefits of Adding PTC to Existing Methods of Operation and Signal and Train Control Systems.

The initial goal of replacing conventional signal and train control systems has ~~been~~ ~~**rejected in favor of developing**~~~~**has been expanded to include**~~ **evolved to development of** PTC systems that augment the existing systems ~~that~~ **which** still have many years of useful life. The current initiatives are to maintain the safety features and business benefits of existing systems while adding functions that cannot otherwise be obtained, ~~**e.g.,**~~ **particularly** enforcement of all speeds and absolute stop where a stop is required. Such functions will reduce human factors **related actions** that contribute to **train** collisions**,** ~~and~~ **overspeed type** derailments and ~~will provide~~ **casualty to roadway workers while providing** for more efficient ~~movement of trains.~~**train management and track utilization.**

It is evident that each current method of train operation and operation in each type or combination of signal and train control system is heavily reliant on human performance to properly issue **and copy** ~~train orders~~ **mandatory directives**, control train speeds and stop where a stop is required. PTC systems have the capability of ~~constantly~~ **systemically** ~~determining~~ **identifying** the location of a train in relation to current speed requirements, speed restrictions in advance, and the point were a stop is required. The systems are capable of enforcing all speed limits and ~~stopping commands~~ **most will enforce all stop commands.** ~~FRA's review of specifications and monitoring of~~Results of actual field tests of several PTC projects indicate that the systems have the potential to intervene before incorrect train orders or excessive speed imperil a train movement or a train passes a point where a stop is required.

~~[Add benefits to MOW employees](need write up from Stotts)~~**[Done - here 'tis.]**

PTC functionality of precisely identifying the location of a train provides the means for the protection of roadway workers. Inputting the location of work zones for roadway workers into the system affords roadway worker protection by enforcing train speeds to that prescribed for the work zone or, when necessary, enforce stopping before a train enters a work zone. This procedure will eliminate dependency upon train crew members to properly control the speed of a train in a work zone and ensure that a train cannot enter a work zone until authorized by the foreman in charge. The Train Guard and ARRC systems plan to provide tracking of on-track vehicles used by roadway workers. The Train Guard, NSLS and ARRC systems will implement a PTC terminal by which roadway workers can communicate with trains and the central dispatching office.

The application of any PTC system to the various methods of operation and wayside signal systems will elevate the existing level of safety for train operations and roadway workers. The centrally controlled systems have potential to achieve the most business benefits, e.g., traffic planning, train pacing, plant utilization, improved productivity in labor, fuel and equipment, etc. However, most PTC systems to some extent will provide means to achieve higher capacity in existing plant and certain economic benefits.

ITCS, ACSES and NJT systems are designed essentially to be installed where the method of operation is by signal indications to provide for closer headway of train movements at higher speeds. These systems will enforce the speeds prescribed by each wayside signal indication while safely permitting higher speeds than that for which the wayside systems were originally designed. The ability to increase track capacity without extensive plant expansion is of significant economic benefit, especially in corridors with limited rights-of-way. The ability to increase train speeds without modifications in the existing wayside system, also a significant economic benefit, improves throughput with resultant increased ridership on passenger trains and improved customer service.

The PTS, CBTM and ARRC systems are potentially capable of being installed in signaled or non signaled territories.

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Installation of these systems in signaled territory may or may not materially impact the existing method of operation except for enforcement of speed and stop commands PTS and ARRC systems will digitally transmit track warrant movement authorities to computers on board locomotives, eliminating the requirement of reading and repeating each authority which is both a safety and economic benefit. All three systems will promote expeditious handling of train operations by providing real-time information for better decision making. In non signaled territory, the systems will provide for closer headway of train movements with resultant increased track capacity.

The proximity warning systems, Train Guard and NSLS, are locomotive on board systems capable of being installed in signaled or non signaled territories. Neither system affects the existing method of operation nor do they require an extensive communications network for support. Train Guard is provided with an on board database and location system that precisely locates a train for speed enforcement. NSLS determines speed enforcement from data obtained from transponders located in the track structure and an on board location determination system. However, a train equipped with either system will enforce all track speeds and safe braking distances between other trains or roadway workers detected within proximity capability of the on board communications system.

The IDOT system will be developed in traffic control territory and progressively incorporate all of the traffic control functions into the PTC system except for wayside signals in areas of flexible block operations. The system will replace operations by signal indications with operations by PTC, a novel method of train operation. The IDOT system will provide opportunity to achieve maximum business benefits while providing enforcement of all train speeds, stop where stop is required and protection of roadway workers.

~~Describe ART effort and report~~

~~A review of the requirements for reporting accidents identified 63 causal factors of accidents that are potentially PTC preventable. The RSAC PTC Working Group assigned a team to identify the PTC preventable accidents in which those causal factors were present. The accident review team was composed of representatives from railroad management, labor and FRA and had many years' experience in railroad operations, signal and train control systems and research and development.~~

~~The accident review team reviewed about 6400 accidents selected from over 25,000 accidents contained in FRA's database for the years 1988 through 1997. Only accidents that occurred on the main track or sidings were reviewed. Four PTC design concepts based on the functionalities of three current projects and the Advanced Train Control Systems (ATCS) Level 40 specifications were used to identify the PTC preventable accidents. The three PTC systems that were used to identify PTC preventable accidents were the Amtrak Incremental Train Control System (ITCS) project; the UP/BNSF Positive Train Separation (PTS) project (now in suspension); and the BNSF Enhanced Proximity Warning System (Train Guard).~~

~~The ATCS Level 40 specifications and the three PTC projects were utilized as four design concepts on the basis of their functionalities. ATCS Level 40 was considered the supreme concept with most functionalities, followed in descending order by ITCS, PTS and Train Guard, Levels 4, 3, 2 and 1, respectively. Each accident was reviewed and, by the process of concensus, placed in the level of PTC deemed capable of preventing that type of accident.~~

~~From review of approximately 6400 accidents, the accident review team identified 685 PTC preventable accidents and 267 accidents that would have been diminished in risk had PTC been in effect. The results of this review for each level is as follows:~~

~~Level~~	~~PTC Preventable~~	~~Risk Diminished by PTC~~	~~Total~~
~~4~~	~~685~~	~~267~~	~~952~~

~~3~~	~~627~~	~~31~~	~~658~~
~~2~~	~~568~~	~~22~~	~~590~~
~~1~~	~~393~~	~~82~~	~~475~~

~~The results show that 952 of the 6400 accidents would have been prevented or the risk diminished by a Level 4 PTC system; 658 of the 952 accidents would have been prevented or the risk diminished by a Level 3 PTC system; 590 of the 952 accidents would have been prevented or the risk diminished by a Level 2 PTC system; and 475 of the 952 accidents would have been prevented or the risk diminished by a Level 1 PTC system.~~

~~The accidents identified by the accident review team's study were provided to the Volpe National Transportation System Center for incorporation into a Corridor Risk Analysis Model where the costs and casualties of the PTC preventable accidents will be identified.~~

~~The results of the accident review team's study further confirms the capabilities of the various PTC systems under development to intervene before a catastrophic incident occurs. In addition, the study provides an initial comparison of the capability of different PTC systems.~~

Positive Train Control Projects

Background

In late 1983, the Canadian National, British Columbia, Canadian Pacific, Burlington Northern, Norfolk Southern, Seaboard System, Union Pacific and Southern Pacific railroads jointly agreed to support an endeavor to identify operating requirements for a communications-based train control system. In 1984, under the auspices of the Association of American Railroads (AAR) and the Railway Association of Canada (RAC), the Advanced Train Control System (ATCS) project office was established. A technical consulting firm, ARINC, was retained to perform a technology assessment and design the system architecture with oversight provided by railroad officials.

The development of the specifications for ATCS took more than three years to complete in an open forum process with railroads, vendors and FRA participating in component drafting committees. The specifications are detailed enough to ensure component interoperability and system safety without limiting vendor ingenuity. The ATCS Specifications, ~~considered the "Bible" of communications based train control systems, is~~are currently managed by the AAR.

Previous PTC Projects

Overview of the Advanced Train Control System (ATCS)

ATCS was built using off-the-shelf equipment and computers and was considered to be comprised of five major systems: the Central Dispatch System, On-Board Locomotive System, On-Board Work Vehicle System, Field System, and Data Communications System. Each of the systems fully complied with the ATCS Specifications in an open architecture.

The Central Dispatch System consisted of two subsystems - a console from which the dispatcher managed train operations that was linked to the ATCS system, and the Central Dispatch Computer. The console provided both an information display and data entry capabilities for the dispatcher. The Central Dispatch Computer was actually two interlinked computers, one that processed information to and from the dispatcher and other ATCS components, and the other that managed train movements with the objective of guaranteeing safe operations and minimizing train delays.

The Locomotive System also consisted of two subsystems - the locomotive display and the on-board computer (OBC). The display provided the interface between the engineer and the OBC; it displayed information about location, route, speed, speed restrictions, maintenance-of-way work locations, messages concerning the train movement, controlled point status and dispatcher advisories. The display contained a terminal from which the engineer could send and confirm information digitally with the dispatcher, field offices and other vehicles. The OBC performed on-board data processing and safety checking and handled data transmitted to and from the dispatcher, other locomotives, maintenance-of-way employees, and coordinated location tracking, enforcement, movement authorities switch monitoring and control, and health reporting. Transponders were placed along the railroad at strategic points (e.g., controlled points, approach to controlled points, interlockings, etc.) for location determination. An interrogater on-board the equipped trains read each transponder providing precise location, and track identification. At selected transponders, the OBC calibrated tachometers that were used to provide location in the intervening distances between transponders. The OBC was equipped a track database which contained information on the transponder locations, distances between transponders, and track configuration.

The Work Vehicle System consisted of two subsystems - a display that provided the interface between a maintenance-of-way foreman and ATCS which permitted the foreman to communicate digitally with the dispatcher or other vehicles and to be aware of nearby track activity and a Track Forces Terminal that performed data processing and safety checking to manage the movement of equipped work vehicles through the ATCS system.

The Field System consisted of wayside interface units (WIU) that provided remote control and monitoring of field devices. The WIUs performed internal data processing and error-checking, commanded the movement of controllable devices (e.g., moveable bridges or power-operated switches), monitored non-controllable and highway rail grade crossing devices.

The Data Communications System was a digital data radio network operating in the UHF radio spectrum. The communications hardware consisted of front end processors (FEP), cluster controllers (CC), base communications packages (BCP) and mobile communications packages (MCP). The FEP is the major entry point from the Central Dispatch Computer into the ATCS ground network and performs train location functions and protocol conversions. Each FEP is connected to serveral CCs. The CC is a routing node in the ground network, manages a base station and performs functions similar to the FEP but over a smaller geographical area (e.g., routing of messages to and from trains or wayside devices under its control). The BCP provides the interface to the ATCS radio frequency and may contain one or more base station radios (each on different channel pairs). Base stations may be connected to the Central Dispatch Office by land lines, leased lines, microwave, fiber optics or radio. The MCP is configured to perform an interface between the RF network and the locomotive computer and display; an interface between a RF network and a WIU; and/or an interface between the ground network and a wayside equipment controller (e.g., code line messages). A MCP is required at each wayside equipment location and on each lead locomotive and selected maintenance-of-way vehicles to transmit and receive messages. The ATCS data transmitted over the network included message protocols that required a handshake (closed loop) in order to become effective or be implemented.

Overview of Canadian National ATCS Projects

Canadian National had three ATCS test or pilot projects between 1987 and 1995. The first, undertaken jointly with the AAR, between 1987 and 1989, was the development of a pilot locomotive display. The project used Canadian National's locomotive trainers and a human factors expert, and the display was tested extensively on CN's locomotive training simulator.

Between 1989 and 1992, Canadian National developed an ATCS Test Bed near Toronto, Ontario to demonstrate the concepts of ATCS. This Test Bed, designed to operate transparently to the revenue operation, consisted of an office system linked to the dispatch system, locomotive systems and Wayside Interface Unit emulators. The system demonstrated the feasibility of train tracking, and the verification and issuance of movement authorities from the office system. The time to deliver and display authorities was less than three seconds. In addition, the tests demonstrated the feasibility of co-existence of train control messages and administrative messages.

Between 1989 and 1995, Canadian National developed a transponder-based system using the AAR ATCS specifications as a foundation for system architecture, functionality, and communications. The system was designed for use in dark territory as a lower cost alternative than CTC, and used Canadian National's Computer-Aided Manual Block System (CAMBS) as a front end dispatch system. It was connected to an ATCS Interface Computer (IC) which converted OCS clearances into ATCS Movement Authorities. The authorities were displayed on the ATCS IC graphical monitor for verification prior to being transmitted to the locomotive.

The territory was 188 miles long and had 13 sidings equipped with power switches monitored and controlled by Wayside Interface Units. The primary method of switch control was through the locomotive, either automatically when the train was operating with a Proceed Authority, and through locomotive engineer action when operating with a Work Authority. Switch position was displayed in the locomotive cab. Switches could also be controlled from the dispatch office for unequipped locomotives and engineering work equipment. The time from initiating the command to control a switch to confirmation on the locomotive display was approximately 15 seconds.

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The system supported enforcement of permanent, temporary and turnout speed restrictions. It also supported the protection of track force work limits, into which a train could enter only after a password, provided by the track foreman by voice radio, was entered into the on-board system by the train crew and verified by the on-board system. The system included reactive enforcement of authority limits, and a form of predictive enforcement to prevent trains from traversing a switch that was not properly set.

In addition to the pilot territory, Canadian National equipped 40 miles in southern Ontario as a test bed. The project was a technical success, but was terminated when the industry appeared to be moving away from the ATCS program, as CN did not wish to be the only one adopting the ATCS technology.

The system was developed by Alcatel Canada, as system supplier and integrator, Vapor Canada and Motorola Canada.

Canadian Pacific Railway ATCS Pilot – Calgary to Edmonton

Canadian Pacific Railway (CPR) operated a revenue-service ATCS pilot on 190 miles of mainline track between Calgary and Edmonton, Alberta, Canada between 1993 and 1995. The objective of the revenue-service pilot was to develop an ATCS system in incremental steps with the constraints that each step must include: 1) a fall-back path to the previous step, 2) a progression path to the next step, and 3) thorough testing before revenue service implementation.

Technology pilots at CPR in the 1980's and 900 MHz radio testing in the late 1980's and early 1990's preceded the operational pilot and proved the technical viability of the major subsystems. Fourteen locomotives were then equipped for ATCS operation, with an additional four being partially equipped as spare locomotives should any of the 14 be removed from service. In-track transponders were then installed between Calgary and Edmonton and 900 MHz ATCS radios were added to existing radio towers to provide continuous radio coverage. During this time, the office dispatching software was upgraded to include a digital communication path to and from locomotives. This path ~~would allow~~ **provided** for the transmission and acknowledgement of clearances to, and the reception of track releases from, locomotives. This was in addition to the existing human interface used for voice dispatching.

The pilot project proved the operational advantages of the electronic delivery of clearances and track releases but also the high cost of maintaining the prototype equipment used. The costs of maintaining such a system were found to be prohibitive, both for retrofitting existing locomotives and for using a transponder-based location tracking system. Reactive and predictive on-board enforcement of authority limits were shown to be effective, although predictive enforcement required more extensive testing before it could be considered for revenue service use. The pilot was shut down in 1995 due to the rising costs of maintaining a prototype system in revenue service. The pilot successfully demonstrated that an incremental approach allows for a manageable migration from existing operations.

~~It is anticipated that an industry focus on high reliability on-board electronics in new locomotive designs will reduce the life cycle costs of on-board equipment. GPS-based alternatives to transponders such as continent-wide DGPS and DGPS with Inertial augmentation, however, must be enhanced to support precision vital location tracking before they can be accepted as a safety-critical solution for railway use.~~

As a postscript, the ATCS frequencies have proven to be a good choice for codeline replacement. CPR is building out a 900 MHz trackside radio network for radio codeline and ~~we~~ envision using ~~any~~ spare capacity to support other trackside data applications. This network will be ready to support ATCS communications in ~~our~~ major corridors when the time comes.

Overview of the Advanced Railroad Electronics System (ARES)

ARES was conceived in 1984 and was similar to ATCS. Following considerable study, the Burlington Northern retained Rockwell International in 1986 to develop and test ARES in a real railroad environment. ARES utilized Rockwell built equipment and was considered to be comprised of three major segments: the Control Segment, the Data Segment and the Vehicle Segment. Each of the segments were built to proprietary specifications developed by the Burlington Northern and Rockwell.

The Control Segment consisted of a console from which dispatchers could monitor the positions and velocities of all equipped vehicles in traffic control territory, automatic block signal territory and non-signaled territory. The Control Segment produced traffic plans, displayed activity at three levels and information about consists, crews, and work orders for each train. In addition, the Control Segment monitored activity to ensure vehicles followed proper operating procedures and warned the dispatcher of violations of limits of speed and authority. Further, the Control Segment performed conflict checking of track warrants and other movement authorities before they were transmitted to trains and maintenance-of-way employees.

The Data Segment consisted of a communications network that provided data paths in the VHF radio spectrum between the mobile equipment, wayside equipment and the control center. It consisted of equipment similar to that of ATCS: FEPs, CC, BCPs and MCPs. Digital data messages were routed by the FEPs and CCs to BCPs at base stations. The base station BCPs provided an interface to mobile vehicles for movement authorities, restrictions, and work orders and to wayside equipment to monitor and communicate the status of hand-operated switches, power-operated switches and signals through the network to the dispatcher.

The Vehicle Segment included both locomotives and maintenance-of-way vehicles. Locomotives were equipped with a receiver for Navstar Global Positioning Satellite (GPS) signals, to calculate train position and speed, a display that informed the crew members about movement authorities, the route ahead, work along the route, and the health of locomotives in the consist. The Vehicle Segment was equipped to apply a full service brake application if the crew was disabled, the train violated its movement authority or speed requirements. The maintenance-of-way vehicles were equipped with a GPS receiver to calculate speed and location, a device to digitally communicate with the dispatcher, and a printer to receive warrants, bulletins and work time in the field. The Vehicle System was equipped with a track database and periodically reported position and speed to the Control Segment. The ARES message protocols also included requirement of a handshake (closed loop) in order to become effective or be implemented.
~~It is not known whether ARES provided for monitoring or prestarting highway rail grade crossings.~~

ARES was implemented on a test bed of 230 miles of track in the Mesabi Iron Range in late 1986. The prototype equipment was installed on 17 locomotive and 3 maintenance-of-way vehicles. The test bed was utilized for more than four years to successfully develop, test and prove ARES technology.

Overview of the Positive Train Separation (PTS)

In 1994, the Union Pacific and Burlington Northern (now Burlington Northern Santa Fe) jointly embarked upon development of a Positive Train Separation (PTS) system. GE Harris Railway Electronics was retained to develop and test PTS. PTS had three major segments: the Locomotive Segment; the Communications Segment; and the Server Segment. PTS utilized the communications network that exists on each railroad with only minimal changes. BNSF used a VHF network and UP used a UHF network. The Locomotive Segment and Server Segment were built to UP/BNSF and GE Harris specifications in an open architecture.

The Locomotive Segment consisted of an on-board computer (OBC) with a cab display. Each locomotive was equipped with a GPS receiver, a differential GPS (dGPS) receiver and a mobile communications package (MCP), connected to the OBC. The OBC contained a track database and performed data processing to monitor location, calculate braking curves, calculate speed, receive authority limits, and apply the brakes if the authority or speed limits were projected to be exceeded. The OBC transmitted position data and violation messages to the server. Buttons on the bezel of the display provided means by which the locomotive engineer could digitally communicate with the dispatcher.

The Server computer was interfaced to a console from which a dispatcher could monitor and direct train movements and to the communications segment for transmitting and receiving data to and from trains. The Server generated movement authorities on the basis of those issued by the dispatcher, established and transmitted authority and speed limits to trains, and received position data and violation messages from trains.

The communications segment on the UP provides data paths in the UHF radio spectrum between the mobile equipment, wayside equipment and the control center. The communications segment on the BNSF provides data paths in the VHF radio spectrum between the mobile equipment, wayside equipment and the control center. Both communications networks consists of equipment similar to that described for ATCS: FEPs, CC, BCPs and MCPs. The message protocols of both systems contained the requirement for acknowledgement (closed loop) in order to become effective or be implemented.

PTS was installed in a testbed extending from Blaine, Washington, to Pasco, Washington, on the BNSF, and between Vancouver, Washington, and Hinkle, Oregon, on the UP, a total distance of about 865 track miles. The segment between Tacoma, Washington, and Vancouver, Washington, is joint trackage on which base stations operating in the UHF radio spectrum was installed in order to achieve PTS interoperability between trains of the two railroads. PTS protype equipment was installed on ~~20~~ **16** locomotives, 10 ~~from each carrier~~ **on the BNSF and 6 on the UP**. The test bed was utilized for more than four years to successfully develop, test and prove PTS technology. The PTS **pilot** project ~~is currently suspended~~ **was** <u>complete</u>**d in August 1998**.

Current PTC Projects

Overview of the Incremental Train Control System (ITCS)

In 1995, the Michigan Department of Transportation, in cooperation with Amtrak and Harmon Industries, was granted funding by the FRA for a demonstration of a high-speed positive train control system on an Amtrak line extending between ~~Chicago~~<u>Porter, Indiana</u>, and <u>Kala</u>mazoo, Michigan. **The system, identified as** ITCS**,** consists of three major segments - the Wayside Equipment Segment, the Communications Segment and the Locomotive Segment. Each of the segments were built to proprietary specifications developed by Amtrak and Harmon Industries.

The Wayside Equipment Segment is comprised of wayside interface units (WIU) at each control**led** point, intermediate signal, electrically-locked hand-operated switch and highway rail grade crossing signal. The WIUs monitor switch position, track circuit occupancy and signal aspects displayed in the traffic control system and the ~~health~~ **status** of highway rail grade crossing**s**.

The Communications Segment consists of two parts - a spread spectrum wide local area network (WLAN) that connects the WIUs to wayside interface unit-servers (WIU-S) that in turn broadcast digital data messages to trains in the UHF radio spectrum. There are 8 WIU-Ss spaced ~~about~~ **up to** 10 miles apart along the railroad. WIUs are slaves to WIU-Ss and continuously report via the WLAN the status of the device(s) being monitored to their assigned WIU-S. The WIU-S broadcasts (open loop) the status reported by the WIUs once every six seconds. Each WIU-S is provided with a track database for the territory it serves including maximum authorized speed and speed restrictions. An office to wayside land line provides means for the control operator to issue or void temporary speed restrictions to the track databases of the WIU-Ss.

The Locomotive Segment consists of an on-board computer (OBC) and cab display. The cab display provides the interface between ITCS and the locomotive engineer by continuously displaying the maximum authorized speed, actual speed, distance to targets, type of targets and target speeds. The OBC stores a database of signal indications, track curvature, gradients, mileposts, civil speed limits, speed restrictions and the locations of all devices with which it may be required to communicate. The OBC continuously calculates braking distances to targets, monitors current speed, upcoming speeds and initiates a full service brake application if the maximum authorized speed is violated or the train is not properly slowed for an upcoming speed restriction or requirement to stop. The OBC establishes a session with each WIU-S when it enters its zone of coverage, verifies that it has an updated track database and expects to receive a WIU-S broadcast every six seconds. The OBC can miss two broadcasts without adverse affects but a missed third broadcast (18 to 20 seconds elapsed time) results in the OBC initiating an automatic brake application~~;~~ **and** stopping the train**, thus safely compensating for the open loop architecture**.

ITCS is designed to prestart highway rail grade crossing signals at train speeds above 80 mph. The grade crossing signals have conventional approach track circuits designed to provide 30 seconds warning for train speeds of 80 mph. The approach to an active grade crossing system is determined by the OBC from the track database. At speeds above 80 mph, a session is then established via the WIU-S with the crossing WIU and the OBC provides an estimated time of arrival. If the crossing WIU indicates it is armed and functioning as intended, the train may proceed at speed and the crossing will provide the required 30 seconds warning. The estimated time of arrival at the crossing is updated every 5 seconds until the train reaches a point 30 seconds from the crossing. If a crossing does not arm or indicates it is not functioning as intended, the OBC will initiate a full service brake application to slow the train before it reaches the crossing. ITCS will restrict the movement of subsequent trains at a failed crossing to 15 mph until the crossing device is repaired.

ITCS was installed in a testbed on Amtrak's Michigan Line between milepost 175 and milepost 195. Since 1995, the testbed has been utilized to develop, test and prove ITCS technology. **Implementation of** ITCS ~~is scheduled to be implemented~~ in revenue service **is scheduled to begin** in mid 1999**.** ~~between milepost 145, near Kalamazoo, Michigan, and milepost 216, near New Buffalo, Michigan~~.

Overview of the Advanced Civil Speed Enforcement System (ACSES)

Amtrak has received FRA approval to install ACSES in the Northeast Corridor (Final order of particular applicability, FR39343, July 22, 1998). ACSES will ~~expand augment~~ **expand** the 4-aspect cab signal system to nine aspects and will utilize transponders of a European design to achieve maximum authorized speeds up to 150 mph, enforcement of civil speeds, temporary speed restrictions and absolute stop. Amtrak has retained Parsons Brinckerhoff to develop, test and implement ACSES using off-the-shelf equipment in an open architecture.

The existing cab signal and train control system utilizes a 100 Hz coded carrier transmitted in the rails to provide for speeds of 20 mph (Restricted Speed), 30 mph, 45 mph and maximum authorized speeds up to 125 mph at code rates of 0, 75, 120 and 180 pulses per minute, respectively. The 9-aspect system will be achieved by the addition of a new 250 Hz coded carrier that, in combination with the 100 Hz coded carrier will provide aspects for enforceable speeds of 80 mph, 125 mph and 150 mph. The addition of a new code rate, 270 pulses per minute, will provide aspects for enforceable speeds of 60 mph and 100 mph.

Transponders will be placed in the approach to speed-restricted zones. The transponders will provide data to on-board equipment that includes distance to the beginning of a speed restriction, type of speed restriction, target speed, average grade to the restriction, distance to the next transponder and message verification information. The on-board computer, through data from a tachometer, will monitor the train's performance and, if necessary, initiate an automatic brake application to prevent entering the speed restriction at a speed above that prescribed.

Transponders will also be placed in the approach to interlockings to provide for enforcement of absolute stop when the interlocking signal displays an aspect requiring stop.

ACSES will permit the continued operation of all the users of the Northeast Corridor ~~at existing speeds. A similar system, compatible with ACSES, is planned for installation on the New Jersy Transit which connects with Amtrak at Newark,~~in New Jersey, ~~and operates over that part of the Corridor extending between Philadelphia, Pennsylvania and New York, New York.~~ **including Conrail, Southeastern Pennsylvania Transportation Authority, New Jersey Transit and Providence and Worcester railroads.**

The intial installation of ACSES is underway between New Haven, Connecticut, and Boston, Massachusetts.

Overview of the New Jersey Transit Project (NJT)

A project similar to and compatible with Amtrak's ACSES system is planned for installation on 132 route miles of the New Jersey Transit (NJT). NJT also connects with Amtrak in New Jersey and operates more than 300 trains daily over that part of the Northeast Corridor extending between New York, New York and Philadelphia, Pennsylvania and over the Atlantic City Line extending between Philadelphia, Pennsylvania and Atlantic City, New Jersey.

Like ACSES, the NJT system will be transponder-based to provide for enforcement of civil speeds, temporary speed restrictions and absolute stop where stop is required. Installation of a nine aspect cab signal system on board NJT locomotives will provide the interoperability necessary to operate at higher speeds and closer headways in the Northeast Corridor.

Overview of the CR/CSX/NS Positive Train Control Platform Project

In 1997, Conrail, CSX Transportation and Norfolk Southern railroads received a grant from the FRA to develop, test and demonstrate an on-board PTC platform.

A determination was made that the design specifications would be object oriented with a standard bus. The objective is to develop an on-board platform which will accommodate inputs from any type of system governing the method of train operation (e.g., block signal systems, ATCS, ARES, PTS, ITCS, etc.) in order to facilitate interoperability.

The project was scheduled in two phases. In Phase I, the plans are to complete the design specifications, issue a request for proposal RFP to define the system hardware, issue a RFP for a prototype, contract for prototype hardware and complete the testing of prototypes. In Phase II, the plans are to issue a RFP for PTC design, contract for PTC design and prototypes, and conduct demonstration testing in the test bed between Manassas, Virginia and Harrisburg, Pennsylvania. The railroads have retained Wabco to develop the design specifications in an open architecture. Wabco and GE-Harris have been retained to develop the interoperable on-board prototypes to be tested in 1999.

~~This project is no longer considered to be a PTC development. It is now considered to be a~~

~~technology development and a field demonstration is unlikely~~A contract for the design of PTC will be issued in 1999, and a demonstration will be conducted in 2000, contingent upon continued FRA funding.

Overview of the Train Guard™

Train Guard™ was conceived in a Burlington Northern labor/management safety committee in early 1993 as a means to make train crew members aware of other trains in their vicinity in non signaled territory. Following the merger of the Burlington Northern and Santa Fe railroads, further development of the proximity warning system was assigned to the BNSF's Technical Research and Development staff which has vigorously pursued Train Guard™ development. The BNSF has retained Pulse Electronics to design and develop system. **Train Guard™ is similar to a proximity warning system installed in early 1997 on the Quebec North Shore and Labrador Railroad in Quebec, Canada by GE Harris.**

Train Guard™ only has equipment on board the locomotive, and consists of an on-board computer (OBC), display, GPS receiver and mobile communications package (MCP) that transmits in the End of Train UHF bandwidth (450 Mhz). The OBC is provided with a track database that includes track curvature, grade, interlockings, signals, crossings and civil speed restrictions. The OBC uses GPS data, tachometer data and gyro data for ~~positioning~~ **location determination**. Every 15 seconds, the MCP broadcasts the locomotive identification number, location, speed and direction. Transmissions received from other ~~trains~~ **locomotives** are displayed showing the other ~~train~~ **locomotives'** identification, distance, speed, direction and time of the last radio communication received. The locomotive engineer is required to acknowledge the proximity of a new train, each signal location (not indication), and upcoming speed restriction. The OBC calculates braking distances to speed restrictions and **other trains and** initiates an automatic brake application if the train is not properly slowed or if the operator fails to acknowledge nearby trains.

Wayside communications networks are not required for Train Guard™ except in areas where MCP transmissions do not have coverage of 5 to 7 miles. In that event, wayside repeaters are installed to provide **that** coverage**.** ~~of 5 to 7 miles~~. The broadcasts of the MCPs on locomotives and repeaters are open loop.

No central office equipment is required to support Train Guard™ though a means is being developed to digitally update on-board databases including temporary speed restrictions. **In the interim, temporary speed restrictions will be manually inputted into the OBC by the locomotive engineer.**

The BNSF is installing an Train Guard™ testbed between Barstow, California and Los Angeles, California, including a maintenance-of-way vehicle, to test Train Guard™ in the railroad environment. Train Guard™ is intended to be a low cost PTC system that fullfills the functionality requirements established and agreed to by the RSAC.

Train Guard™ is essentially a communications-based train stop system and for safety reasons still has to pass the hurdle of FRA acceptance as a PTC system.

Overview of the Communications Based Train Management System (CBTM)

The CSX railroad has embarked upon the development of a PTC system identified as CBTM. CSX has retained Wabco **Railway Electronics** to develop and test CBTM using the object oriented design concept and the CR/CSX/NS joint platform design. The CBTM design will be an open architecture.

CBTM will provide for the Railroad Safety Advisory Committee's (RSAC) core features in non-signaled territory: prevent collisions between trains; prevent overspeed of trains; and protect maintenance-of-way work zones from unauthorized intrusion by trains. CBTM will provide databases at wayside Zone Controllers that control train movements, issue movement authorities; issue targets for speed reductions, monitor switch positions; and protect maintenance-of-way work zones. The on-board computer (OBC) will calculate braking distances, calculate the far limits of authority, and initiate an automatic brake application at speeds above ~~5~~ **8** mph when a violation is projected.

A testbed in non-signaled territory has been selected for testing CBTM concepts. The objective of CBTM is to design a system that meets the RSAC core objectives while providing an approach that permits the locomotive fleet to be economically equipped and interoperability achieved.

Overview of the Alaska Railroad Corporation Project (ARRC)

Early in 1998, the Alaska Railroad Corporation (ARRC) launched a program to install Precision Train Control™ (PTC**™**) systemwide. The AARC PTC**™** is a development of GE Harris, the System Engineer on the project.

~~The AARC~~ **PTC™** is a ~~derivative~~ **product** of the UP/BNSF PTS **pilot** project. Like PTS, PTC**™** has three major segments: the Locomotive Segment; the Communications Segment; and the Server Segment, which requires support of a computer-aided dispatching (CAD) system. Unlike PTS, PTC**™** will include a Track Forces Terminal (TFT) for roadway employees. The TFT will provide location and tracking of maintenance-of-way on track vehicles and digital communications for obtaining and releasing work zones for the protection of roadway employees.

The ARRC has completed installation of a communications system to support PTC**™**. A CAD system has been delivered and is scheduled for implementation in the first quarter of 1999. Deployment of PTC**™** is scheduled for the first quarter of 2000.

Emerging PTC Projects

Overview of the Norfolk Southern Location System (NSLS)

NSLS is recently emerging system for which specifications have not yet been completed or published. It is a proximity warning system that is being designed in-house on the Norfolk Southern railroad. NSLS is similar to Train Guard™ in that its concept is to inform train crew members about other trains in the vicinity.
~~The NSLS design is proprietary to Norfolk Southern.~~

NSLS will utilize transponders located at each signal location that provide information to on-board computers about the location, distance to and location of the next two transponders, maximum authorized speeds and civil speed restrictions. The on-board computer (OBC) will consist of an interrogator for reading transponders, a display and a mobile communications package (MCP) for transmitting data from the OBC. NSLS utilizes a tachometer to determine position between transponders. When a train passes a transponder, the locomotive identification, location, speed and direction will be periodically broadcast in the Norfolk Southern's End of Train Device ~~VHS~~ **VHF** radio spectrum. The ~~VHS~~ **VHF** broadcast is expected to cover about seven miles. When another train enters or is within the coverage of a train, its identification, speed and direction will be displayed to the locomotive engineer and acknowledgement required. When two opposing trains identify the same second transponder in advance, a safe braking distance is determined causing the OBC to initiate automatic brake applications on both trains.

The Norfolk Southern is continuing to develop the design of NSLS, including possibly displaying signal aspects on the display. ~~This system, like Train Guard, is an open loop communications-based train stop system and yet to be determined acceptable as a PTC system.~~NSLS is intended to meet the PTC RSAC objectives. **However, like Train Guard™, NSLS is considered to be a communications-based train stop system and is yet to be determined acceptable as a PTC system.**

Overview of the Industry/FRA/Illinois Department of Transportation (IDOT) Positive Train Control Project

The FRA ~~instated~~ **instituted** this program jointly with the railroad industry and IDOT to design, test, build and install a PTC system on a segment of the Union Pacific railroad extending between Springfield, Illinois, and Mazonia, Illinois, a distance of about 120 miles. The railroad industry agreed to participate with the FRA and IDOT through the Association of American Railroads (AAR) and its subsidiary, The Transportation Technology Center, Inc. (TTCI).

The objectives of the project are to develop, test and demonstrate **a** cost-effective and interoperable PTC system, including flexible block operations, ~~interoperability~~ and advance activation of highway rail grade crossing signals in a corridor with both freight and passenger service. In addition, the system must meet the safety objectives of preventing train-to-train collisions, enforce speeds and speed restrictions, and provide protection for maintenance-of-way employees and their equipment.

On July 15, 1998, TTCI issued a request for proposal seeking a System Engineer for the PTC program. The submissions of the offerors are being reviewed ~~and a selection is expected to be made in October 1998~~. **in preparation for selection of a System Engineer.** The project is projected to require four years to develop, test and demonstrate.

COMPARISON OF THE PTC PROJECTS

The ATCS specifications were developed by the railroad industry with participation by suppliers and the FRA. The intent was to provide for both interoperability across railroad control systems and interchangeability between supplier products for such systems. The ATCS specifications ~~provided for~~ **set forth** a range of communications-based applications including~~, health monitoring, codeline replacement, work order reporting and positive train control to be hosted on the communications network. The specifications included standardized communications methods, train control messages, and the response to those messages.~~**standardized communications methods, message protocols, logic to handle the excange of messages, health monitoring, codeline replacement, work order reporting and positive train control.**

~~The ATCS specifications provided for a modular approach to train control implementation. The railroads could build train control systems to meet the requirements for various operating conditions ranging from light density to heavy density lines. ATCS was not broadly enough based to include many of the systems and technologies currently being implemented, tested or designed.~~

The ATCS specifications provided a basis upon which railroads could build train control systems to meet the requirements for various operating conditions ranging from light density to heavy density lines. Four levels of ATCS functionalities were identified: Level 10 for light density lines included digital transmission of track warrants without enforcement; Level 20 included the functionality of Level 10 with train tracking and work orders but not enforcement; Level 30 included the functionalities of Levels 10 and 20 with enforcement; and Level 40 included the functionalities of Levels 10, 20 and 30 with control of switches and routing. Levels 10, 20 and 30 could be used with or without signal

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systems but Level 40 was specifically for traffic control type territory in which wayside signals could be removed and moving block operations implemented. A train equipped for either level of ATCS would be interoperable in the other levels to the extent the on board functionalities permitted.

All of the PTC projects have similarities to the ATCS specifications. Most, if not all, specify equipment and communications built to ATCS specifications. However, not all railroads have extensive data communications systems and among those that do, not all will support the ATCS specifications for standardized radio spectrum, communications methods, message protocols and logic for exchanging messages. Accordingly, each of the PTC systems under development have modified equipment or communications protocols to the extent they are exclusive to that project, conflicting with the objective of interoperability among the various systems.

A Matrix of PTC Systems**,** ~~(Appendix ___)~~ **Appendix C,** identifies the characteristics of the systems in ~~the~~ 10 PTC projects. The matrix is composed of 14 categories containing data relative to each PTC system. Four categories, Architecture, Office Segment, Communications Segment and Locomotive Segment, identify the functionalities that set the systems apart from one another in terms of puissance and deficiency with regard to the safety of train operations.

~~The PTS, and ARRC systems will be centrally controlled from CAD systems while the ITCS, ACSES, CBTM, Train Guard, NSLS, and NJT systems will be distributed systems even though installed in centrally dispatch systems.~~

The PTS, IDOT CBTM and ARRC systems will be centrally controlled from CAD systems while the ITCS, ACSES, Train Guard, NSLS, and NJT systems will be distributed systems even though installed in centrally controlled systems.

~~Only one system, IDOT, has the objective to be a stand alone system. Three systems, ITCS, ACCES and NJT are integrated systems. Five systems, PTS, Train Guard, NSLS, ARRC and CBTM are overlay systems. The CR/NS/CSX project is a developing platform technology that will be utilized in the IDOT and CBTM projects~~.

Two systems, IDOT and ARRC, have the objective to be a stand alone systems. Three systems, ITCS, ACCES and NJT are integrated systems. Four systems, PTS, Train Guard, NSLS, and CBTM are overlay systems. The CR/NS/CSX project is a developing platform technology that will be utilized in the IDOT and CBTM projects.

The ITCS, ACSES and NJT systems are most potent from the perspective of safety of train operations. (conclusion before analysis?**Read system descriptions and the matrix**) These systems derive functionalites to enforce all train speeds and stop where stop is required from wayside signal systems that are designed and arranged to provide proper switch position, track and route integrity and spacing of trains. Protection of roadway workers is achieved by inputting work zone locations in databases on board the locomotive via transponders. The strength of these systems is integration with the wayside signal system where safety resides except for speed enforcement. The wayside signal indications provide a redundant overview to the locomotive engineer about the authority displayed in the locomotive cab. Further, the wayside signal systems provide immediate fall back to operations by signal indications in the event of failure of on board equipment. ACSES and NJT utilize proven technologies available off the shelf and, unlike ITCS, are not dependent upon an extensive communications network between trains and the control center or wayside. A weakness in the ACSES and NJT systems is ensuring transponder data is correct, especially in portable transponders used for the protection of roadway workers.

The PTS, CBTM and ARRC systems derive functionalities to enforce all train speeds and stop where stop is required from movement authorities issued to each train by CAD systems. These PTC systems require a communications network with high reliability and availability for transmitting and receiving data between trains and safety computers located in the central office or on the wayside. The strength of these systems lay in databases either on board or on the wayside that, in connection with GPS technology, provide precise train location for enforcement of all speeds and stop where a stop is required. Protection of roadway workers is accomplished by inputting the work zones and their associated speeds into the databases. In the CBTM system, the requirement for hard copy of block authorities provide a redundant overview of the authority displayed in the cab. A weakness of ~~these~~ **the PTS and CBTM** systems is that in signaled territory, signal indications do not provide a reliable redundant overview of the authority displayed in the cab. The CBTM system does not enforce speeds or stop commands at speeds below 8 miles per hour. ~~Except in traffic control territory, failure of the on board equipment in the PTS and ARRC systems will require fall back operations to copying and repeating mandatory directives for movement of the train~~. **Failure of the on board equipment in the ARRC system, and PTS in automatic block signal or non signaled territory, will require fall back operations to copying and repeating mandatory directives for movement of the train.**

The Train Guard and NSLS systems are proximity warning systems that derive functionality to prevent train-to-train collisions from the reception of data transmitted by other trains in the radio spectrum. They are locomotive on board systems extraneous to existing methods of operation or wayside signal systems, an irrelevancy **that** precludes enforcement of stop where stop is required, e.g., at the end of the limits of authority or a wayside signal aspect indicating stop. Wayside signal indications will provide redundant support of data displayed on board for the movement of trains but not for the protection of roadway workers. No such redundancy will exist in non signaled territory. The weakness of both systems is the dependence upon antennas on locomotives that may as a result of damage or deterioration unknowingly degrade transmission and reception of train location data in an open loop broadcast.

The IDOT system will derive functionalites to enforce all train speeds and stop where stop is required from movement authorities issued by the CAD system and central safety computer of which the wayside traffic control signal system will become an integral part. The system will require a communications network with high reliability and availability for transmitting and receiving data between trains and safety computers located in the central office or on the wayside. The strength of this system is complete integration with the wayside signal system where safety resides to provide proper switch position, track and route integrity and in databases either on board and/or on the wayside that, in connection with GPS technology, provide precise train location for enforcement of all speeds and stop where a stop is required. Protection of roadway workers will be accomplished by inputting the location of work zones and their associated speeds into the databases. Interoperability with other PTC systems will increase the vigor of the IDOT system. The development of flexible block operations, desirable for increased track capacity, will result in the removal of wayside signals. Elimination of the wayside signals are an economic benefit but exposes a weakness by excluding redundant support of information displayed on board the locomotive. Special requirements will be necessary to mitigate hazards associated with train movements experiencing failure of on board PTC equipment since there will be no wayside signals in essentially a traffic control system.

Benefits of Adding PTC to Existing Methods of Operation and Signal and Train Control Systems.

The initial concept of optional utilization of conventional signal and train control systems has evolved to development of PTC systems that augment existing wayside systems which still have many years of useful life. The current initiatives are to maintain the safety features and business benefits of existing systems while adding functions that cannot otherwise be obtained, particularly enforcement of all speeds and absolute stop where a stop is required. Such functions will reduce the human factors that contribute to train collisions, overspeed type derailments and casualty to roadway workers while providing for more efficient train management and track utilization.

It is evident that each current method of train operation and operation in each type or combination of signal and train control system is heavily reliant on human performance to properly issue and copy train orders, control train speeds and stop where a stop is required. PTC systems have the capability of systematically identifying the location of a train in relation to current speed requirements, speed restrictions in advance, and the point were a stop is required. The systems are capable of enforcing all speed limits and most will enforce all stop commands. Results of actual field tests of several PTC projects indicate that the systems have the potential to intervene before incorrect train orders or excessive speed imperil a train movement or a train passes a point where a stop is required.

PTC functionality of precisely identifying the location of a train provides the means for the protection of roadway workers. Inputting the location of work zones for roadway workers into the system affords roadway worker protection by enforcing train speeds to that prescribed for the work zone or, when necessary, enforce stopping before a train enters a work zone. This procedure will eliminate dependency upon train crew members to properly control the speed of a train in a work zone and ensure that a train cannot enter a work zone until authorized by the foreman in charge. The Train Guard and ARRC systems plan to provide tracking of on-track vehicles used by roadway workers. The Train Guard, NSLS and ARRC systems will implement a PTC terminal by which roadway workers can communicate with trains and the central dispatching office.

The application of any PTC system to the various methods of operation and wayside signal systems will elevate the existing level of safety for train operations and roadway workers. The centrally controlled systems have potential to achieve the most business benefits, e.g., traffic planning, train pacing, plant utilization, improved productivity in labor, fuel and equipment, etc. However, most PTC systems to some extent will provide means to achieve higher capacity in existing plant and certain economic benefits.

ITCS, ACSES and NJT systems are designed essentially to be installed where the method of operation is by signal indications to provide for closer headway of train movements at higher speeds. These systems will enforce the speeds prescribed by each wayside signal indication while safely permitting higher speeds than that for which the wayside systems were originally designed. The ability to increase train capacity without extensive plant expansion is of significant economic benefit, especially in corridors with limited rights-of-way. The ability to increase train speeds without modifications in the existing wayside system, also a significant economic benefit, improves throughput with resultant increased ridership on passenger trains and improved customer service.

The PTS, CBTM and ARRC systems are potentially capable of being installed in signaled or non signaled territories. Installation of these systems in signaled territory may or may not materially impact the existing method of operation except for enforcement of speed and stop commands PTS and ARRC systems will digitally transmit track warrant movement authorities to computers on board locomotives, eliminating the requirement of reading and repeating each authority which is both a safety and economic benefit. All three systems will promote expeditious handling of train operations by providing real-time information for better decision making. In non signaled territory, the systems will provide for closer headway of train movements with resultant increased track capacity.

The proximity warning systems, Train Guard™ and NSLS, are locomotive on board systems capable of being installed in signaled or non signaled territories. Neither system affects the existing method of operation nor do they require an extensive communications network for support. Train Guard™ is provided with an on board database and location system that precisely locates a train for speed enforcement. NSLS determines speed enforcement from data obtained from transponders located in the track structure and an on board ~~dead reckoning~~ **location determination** system. However, a train equipped with either system will enforce all track speeds and safe braking distances between other trains or roadway workers detected within proximity capability of the on board communications system

The IDOT system will be developed in traffic control territory and progressively incorporate all of the traffic control functions into the PTC system except for wayside signals in areas of flexible block operations. The system will replace operations by signal indications with operations by PTC, a novel method of train operation. The IDOT system will provide opportunity to achieve maximum business benefits while providing enforcement of all train speeds, stop where stop is required and protection of roadway workers.